Experiments Upon the Explosions of Hydrocarbon Mixtures

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THESIS OUTLINE.

Experiments Upon Explosions of Hydro-Carbon Mixtures.

I. Introduction.

- A. Desirability of such experiments.
- B. Reference to previous experimental work.
- C. Object of present series of experiments.

  (See plan of experiments.)

  - a. Heat produced by explosion of H-C mixture.
  - b. Duration of pressure.
  - c. Rate of combustion and explosion.
  - d. Effects of different mixtures.
  - e. Influence of water jacket.
  - f. Effects of compressing the charge.

II. Description of apparatus.

- A. Explosion chamber.
  - a. Design.
  - b. Construction.
- B. Special indicators.
  - a. Design.
  - b. Operation.
- C. Ignitor.
  - a. Design.
  - b. Operation.
- D. Gas compressor.

III. Experimental results. Method of conducting experiments; results, tables and data on series of experiments outlined. (See D. Clerk on Gas Eng. pg 96 top).

IV. Conclusion. Deduction from results of experiments.

EXPERIMENTS UPON THE EXPLOSIONS OF HYDROCARBON MIXTURES.

Introduction.

For a great many years articles have appeared at intervals in the scientific papers and magazines on the heat and explosion engine, but not until recently has the subject been considered of any great importance. After a time a magazine devoted exclusively to gas engine matter was started, and has been successfully published for several years. Within the last ten years a few text books have been produced treating of the design and operation of gas engines, but so far none seem to fill the requirements of a satisfactory treatise, since the books do not deal in full with the detailed fundamental principles.

Desirability of such Experiments.

In the designing of machinery it is quite necessary that one should be familiar with the working of that particular machine on which work is to be done. So it is with gas engine designing. One should know in full the details of the working of the gas engine. It is fully of as much importance that the operator too, should know the details of the working of the engine as the designer, and this must be true before the gas engine will improve, for it is the operator who decides, or makes it possible to decide, as to whether the design of the engine is a good one or not, and if not, where some improvements might be made. When the designer and operator become as well acquanted with the gas engine as others are with the steam engine, it is quite probable that the gas engine will be so far superior to the steam engine that the latter will be forgotten entirely.

The gas engine of the present day has a thermal efficiency of about 20%, while the best steam engines have but 15%, and the steam engine is as near perfect as it will ever be, while the gas engine has many chances for improvements. Notwithstanding the fact that explosive engines were suggested fully as soon as steam engines, the gas engine failed to advance with the steam engine on account of the numerous difficulties to overcome, and the lack of scientific investigation.

Until recently the gas engine was of no great importance, and the experimental work was and is at the present day not as extensive as it should be. In all of the smelters and places where large furnaces are used the gasses which are allowed to escape could be utilized to good advantage for mechanical powers. This gas could be used for motive power not only in these works but in the surrounding manufacturing establishments also.

Since natural gas and oil have been found in such great abundance, and in different parts of the country, the use of the gas and oil engine is growing more and more, and promises to be the source of mechanical power.

Reference to Previous Experimental Work.

The first use of an explosive for motive power was proposed by Huygens in 1680. Papin in 1690 continued Huygen's experiments, but without success. The methods used was a fairly practicable one. The explosion was used indirectly; a small quantity of gunpowder

exploded in a large cylindrical vessel, filled with air, expelled the air through check valves, thus leaving after cooling a partial vacuum. The pressure of the atmosphere then drove a piston down to the bottom of the vessel lifting a weight or doing other work.

The first real gas engine described in this country is in Robert Street's patent, No. 1983, in 1794. It contains a motor cylinder in which works a piston connected to a lever, from which lever a pump is driven. The bottom of the motor cyninder is heated by a fire; a few drops of spitits of turpentine being introduced and evaporated by the heat, the motor piston is drawn up and air entering mixes with the inflamable vapor, the application of a flame to a touch hole causing explosion, and the piston being driven up forces the pump piston down, so performing work in raising water. The details as described, are crude; but the main idea is correct and was not improved upon in practice until later.

Patent recors have been called a manual of the history of inventions, and in such records we find that William Barnett, an Englishman, was probably the first (in patent specifications of 1838) plainly to claim the broad principles which still govern explosive gas engines. Barnett describes three different engines, one of which is as follows: The engine consists of a working cylinder, near the working cylinder is an air pump and beside the air pump lies a gas pump. These two compression pumps force air and gas into a loading chamber. When the working piston is on the lower dead center the piston valve opens and connects load chamber and working cylinder and also opens the ignition inlet, the charge being ignited by a flame.

After the piston has been driven by explosion to the upper dead center, the piston valve goes down, opens connection between working cylinder and air pump which is also descending, and thus the products of combustion are drawn from the working cylinder, and, on the up stroke of the air pump piston, expelled from the engine. Barnett finally claimed that it was not necessary to draw out the burnt gasses but that they could escape into the open air through a valve.

In describing variations of his engine, Barnett also claimed ignition by means of platinum sponge, which glows the more readily because of the compression of the gas mixture.

From the great number of variations described, both for engines and ignition apparatus, it is evident that Barnett was well aware of the value of his invention, and was attempting in his patent specifications to cover all possible forms. Although the gas engine designers of the present time can see plainly that Barnett's design would not have produced a practical working engine, nevertheless it must be emphasized that Barnett's ideas include all that is fundamental in the theory of the modern gas engine:

1. Compression of the gas mixture before ignition.

2. Combustion in the working cylinder.

3. Dilution of the gas mixture with combustion products remaining in load chamber.

4. Ignition on a dead center.

After this first effort to design an operative gas engine, there was a long period of inactivity. The clearly expressed fundamental ideas of Barnett's specifications were forgotten, and not until 1860 was the first gas engine made; one which actually worked and which to some extent was used in service, namely, that of the Frenchman, Lenoir. Although the principles used by Lenoir for his engine had not the fundamental value of Barnett's , nevertheless, to Lenoir must be conceded the great merit of being the first to whose patience and energy we owe a practical solution of the problem of the gas engine. He may, therefore, rightly be considered as the inventor of the gas engine, for it is an immeasurably greater merit to carry into execution a creative thought than merely to apprehend it.

The Lenoir in outward appearance and method of utilizing expansive power, closely resembles the steam engine. The gas is drawn in for a part of the stroke, then it is ignited by an electric spark, and the piston is then driven the remainder of the stroke by the force of the explosion. On the return the same operation is repeated. The Lenoir gas motor was therefore a double acting non-compression engine.

Al~~l~~most immediately after the appearance of the Lenoir engine, Gustave Schmidt published ~~has~~ in the year of 1861 a study of its theory, and he showed how its efficiency might be very greatly increased by compressing air and gas before combustion in the engine. Although Barnett had designed his gas engine in 1838, for a compressed gas mixture, this fundamental principle was but very slowly introduced in practice.

Mr. Dugald Clerk made some very extensive experiments about 1880. He endeavored to ascertain the results of different proportions of air and gas. He did not confine himself to the one gas, but used several gasses in the same vessel, under the same conditions Mr. Clerk found that certain proportiohs of gas and air must be used to produce the best explosions. This proportion was not the same for all gasses, but varied with the composition of the gas. Mr. Clerk failed to try the effect of different jacketing, therefore his experiments were not as complete as they might have been.

I shall not consume the time and space to enumerate all the experiments that have been performed. Enough of the most important experiments have been mentioned to verify the statement that was made and to show that the author is justified in performing the experiments outlined below.

Object of Present Series of Experiments.

The object of the present series of experiments is: To ascer-
(Heat produced by explo. of h-c mix.)
tain as nearly as possible the heat produced by the explosion under certain conditions. It is true that the total amount of heat developed may be calculated matematically if sufficient data is available, but it is also true that the conditions are continually changing. The loss of heat, due to radiation, through the walls of the cylinder, is varying all the time. The initial temperature of the charge is never the same. The composition of the charge is different each time. The ratio of the mixture will control the amount of heat and also the time of burning. The latter is of most importance, yet the former is an important factor.

The only way of obtaining knowledge in regard to these things is by experiments. The mathematical calculations of these results are never in accordance with observed facts, and experimental results are only approximate.

Duration of Pressure.

The second object of this experiment will be to ascertain the duration of pressure. The pressure is influenced by the heat of the explosion, and depends upon the initial temperature and character of the mixture; and the pressure and temperature are dependant upon each other, Accordingly in order to find either the pressure, or temperature, one must know the other. Then using the general formula

$$\frac{PV}{T} = K$$

the other is obtainable.

Rate of Combustion or Explosion.

The third object is to find rate of combustion or explosion of different mixtures after they have been admitted under different pressures and initial temperatures. The rate of combustion should be studied both in conjunction with and apart from the first, namely, heat of the explosions. It is undoubtedly true, that, mixtures having the same amount of hydrocarbon and air, will have different rates of comnustion. Then, since this is true, it is well that one should know when and why it is true, and how to eliminate it.

Effects of Compressing the Charge.

The mixture of the hydrocarbon will have some influence as stated before, causing either an explosion or a slow combustion. The water jacket will make some difference which might be worth knowing, hence the study of its influence.

Description of the Apparatus.

In order that these experiments might be performed it was necessary to design and construct a special piece of apparatus. A few words of explanation in regard to this apparatus are necessary. The apparatus used will be something similar to that used by Dugold Clerk in his experiments. Mr. Clerk's apparatus consisted of a cylinder, ignitor and indicator. The indicator was of the Richards type, but instead of reciprocating drum, one that revolved was used. Mr. Clerk employed different means for operating the indicator drum that was used in this set of experiments. He used a falling body for revolving indicator drum, and regulated the motion of the drum by means of a small fan. The ignitor for Mr. Clerk's experiments was placed at the bottom of the chamber.

Explosion Chamber.

In designing the explosion chamber, it is of great importance to have i strong enough to withstand ~~t~~ more than the greatest possible pressure which it will be required to stand. The chamber should also be designed so that various kinds of jacketing might be used. Before and during the machining, the casting should be examined closely to see that it is of the right degree of hardness and solid throughout. If satisfactory it must be machined so that the parts fit perfect and so tightly t at the hot gasses ca not escape for if a leak existed the results obtained from the experiments would be incorrect. The explosion chamber is cylindrical, seven inches in diameter and eight inches long, inside measurements. The heads were designed so hat they would act as supports for the jacketing. The wall and heads of the cylinder are three-fourths of an inch thick. This is sufficient to withstand a pressure of three hundred pounds or more per square inch. One of the ~~g~~ heads is so designed that indicator, ignitor and charging valve may be connected there without making it weaker than the reat of the cylinder.

Special Indicator.

In order to ascertain some of the results of the explosion , it is necessary that an indicator be used and for this an gas engine indicator will fulfill all requirements. The indicator to be used in these experiments is a Thompson No. 2 indicator constructed by the American Steam Guage Co., and was designed especially for such work as this. Since there is no moving piston in the apparatus as in the gas engine, some means must be provided by which the drum of the indicator may rotate, and, too, the motion must be such that the drum will revolve uniformly through a given arc in a known length of time. For this motion the mechanism of a clock is to be used, and by proper regulation and adjustment the required motion may be had.

The card is placed on the deum. The charge of explosive mixture is admitted into the chamber and the drum is started to rotating. As soon as the drum is running at a uniform rate the charge is ignited and the indicator card is taken.

Ignitor.

The ignitor consistsof two terminals attached to an electric battery. One of these terminals is screwed into one head of the cylinder. The other passes through and is insulated from the same cylinder head. To ignite the charge, these two terminals are brought in contact and then separated. Upon separating a spark is made which lights the ~~ignitor~~ mixture and this is followed by the explosion.

Gas Compressor.

In order to study the action more t oroughly, it is necessary that the charges have not only different ratio of mixtures but also different initial pressures and in order to have the initial pressures vary it is neces ary that we have some form of pump or compressor. For these experiments an ordinary single act ng hand-operated compressor will be used. It will not be necessary to explain the working of the compressor.

The method outlined for performing the experiments was to first explode a few charges in the chamber to insure that it was safe and in normal conditions. The first experiments will be to make several explosions in the vessel without any jacketing. The initial and final temperatures of the wall of the vessel will be taken for each explosion, ~~as~~ also the initial temperature of the charge. An indicator card will be taken from which the pressure at any instant may be found. By analyizing the gas after each explosion, knowledge may be obtained as to whether or not the exolosion mixture contains the right proportion of air and gas. If not, which are in excess, and what per cent. After making a sufficient number of such experiments, the conditions will be changed, such as the initial temperature and pressure, and more readings taken. After obtaining all data possible from the vessel without any jacketing, a jacket of water will be used and the same list of experiments will be performed. Both still and running water will be used. The water will be measured in order to find the amount of heat absorbed by jacket. The initial and final temperatures of the water being taken in the case.

The drum of the indicator revolving at a known rate and uniformly, the time of ignition as noted and the rate of combustion, the maximum pressure, and duration of pressure, is shown by the indicator card. If the condition of the explosive mixture is known, also the products of combustion, the heat pro duced by the ex-sion can be easily calculated.

Knowing the initial and final temperatures of the water, also the amount, one can readily calculate the amount of heat required to produce this charge, hence the heat of the explosion approximately. After a sufficient number of experiments, have been performed with the water jacket, a jacketing of asbestos will be used and the same experiments will be made as in the two previous cases. When sufficient data has been collected from these experoments they will be tabulated and compared.

After having everything but the casings in readiness for the-experiments, it was learned that those could not be finished. The only possible way of performing experiments similar to those planed, would be by the use of a gas engine, and since the University is fortunate enough to be the possessor of one, that wa used for the experimental apparatus.

The engine is rated at seven horse power, running at 260 revolutions per minute. It is classed as a four cycle horizontal gas engine having a single cylinder of 6 and 1/2 inches in diameter and 11 inches stroke

11 inches stroke. The admission and exhaust valves are of the Poppet type and are operated by links and cams, which cause the valves to open once in every two revolutions of the crank shaft. The governor is of the Wat-hit-and-miss type, and is operated by a belt from the crank shaft The gas inlet valve is operated by a poppet hitting or missing the stem of the valve, When the speed is above normal the governor throws the stem of the valve to one side causing the toppet to miss and the gas inlet valve to remain closed. In this case the air alone would pass through the engine and the failure of an explosion would reduce the speed of the engine.

Owing to the lateness of the term it was impossible to perform an elaborate set of experiments as oullined in the first part of this paper, but such experiments as could be performed readily and accurately were made.

A few words of explanation in regard to those experiments might be of some help to the reader.

The engine was run for awhile to make sure that it was in good running order. The indicator was attached and a break put on so that a constant load might be maintained. The gas and air inlets were adjusted so that an explosive mixture of known proportion was being used in the engine. After the engine had attained a normal speed an indicator card, speed, number of explosion, and the brake load, was taken. After performing all of the experiments, the indicator cards were found to be incorrect, on account of the piston int erfering with the communication between the cylinder and indicator.

Conclusion.

From a study of the subject, one might draw some such conclusion as this: By a careful and unprejudiced study of the gas engine some very important advancement might ~~be~~ made in the construction and operation thereof. The author is safe in saying that the successful engine will be the one compressing the charge before ignition.

since the pressure produced by any given mixture are proportionate to the pressure~~s~~ before ignition. The time of ignition was found to depend on the size of the vessel. The shape has a great effect upon the rate of combustion. Where it is cylindrical and large in ~~proportion~~ diameter, proportional to its actual length, ignition is extremely rapid, the flame is confined and and is rapidly depleted by the cylinder ends, and so shoots through the whole mass. Mr. Clerk said that by so arranging the explosion space of a gas engine that some mechanical disturbance is permitted, it ~~it~~ is easy to get any required rate of ignition even with the weakest mixture. The maximum pressure is increased by rapid ignition. The most important factor, the ones which control almost entirely the working of the gas engine are: Composition, initial temperature, and initial pressure of charge.

The designer of the engine will regulate the amount of compression, and the operator must regulat composition and the initial temperature. Therefore the success of the gas engine will depend conjunctively upon the designer and operator.